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ATTACHMENT 9 WIND ANDWAVE APPENDIX

ENVIRONMENTAL MANAGEMENT PROGRAM

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ATTACHMENT 9
CAPOLI SLOUGH HABITAT REHABILITATION AND ENHANCEMENT PROJECT
ANALYSIS OF EFFECTS OF CAPOLI ALTERNATIVES ON WIND FETCH AND PROBABILTY OF WAVE GENERATED SEDIMENT SUSPENSION

The Upper Midwest Environmental Sciences Center (UMESC) of the U.S. Geological Survey (USGS) developed geospatial models based on wind and water depths to assist in the planning for Habitat Rehabilitation and Enhancement Projects (HREP), under the Environmental Management Program (Rohweder et al. 2008). UMESC also performed model runs on preliminary alternatives for selected HREPs, including Capoli Slough. Based on further planning, modifications were made to the alternatives being considered for Capoli and the models were run for these alternatives.
Chesapeake

EVALUATION AREA

The Capoli Slough study area is approximately 821 acres in size lying near RM 657.2 and between the main channel of the UMR and Lake Winneshiek. Several island stabilization, closures, and island restoration configurations were developed for detailed evaluation (figure 1).

The boundaries of the areas of influence are depicted in figure 2. The secondary channel, Capoli Slough, was treated as one area (Cap slough - 41 acres). The area where the proposed features would be constructed and as a result would be most affected by the proposed is depicted as major influence area (Cap major - 780 acres). A larger area outside the major influence area would be affected, but to a much lesser degree, with the reduced wind fetch and wave sediment suspension (Cap minor - around 1,200 acres). The minor area was determined based on the area that would have at least a reduction of 10% in the days when orbital velocity would not exceed 0.1 meters per second from Alternative E5 compared with the future without action (see figure 2).

PLAN COMPONENTS

Existing Conditions – The latest land cover database for lower pool 9 was completed in 2000 and was used in the models for existing conditions.

Future Without Project Conditions – Predicted future with and future without project conditions are used in the planning of all HREP. The prediction of future without project conditions assumes no habitat restoration measures will occur in the Capoli Slough project area, and natural forces will continue to change the area in a manner similar to what has occurred in lower pool 9 since the creation of the pool in 1938. Based on the rate of island loss for the period 1940-2000 (table 1), it is estimated that the remaining islands in the Capoli Slough complex will be gone within 10-20 years.

Table 1. Changes in Capoli Slough islands areal extent

Island Loss

Year	Acres	Acres Lost	% Loss	Acres Lost/Year
1940	74			
1975	50	24	32	0.7
1989	32	18	36	1.3
1998	24	8	25	0.9
2000	16	7	29	3.5
Cumulative		50	68	0.8

Alternatives - Features were combined to evaluate alternative plans, which are summarized in Table 2. It was not possible to run the model for every potential combination of alternative measures, so a selected number of alternatives were evaluated. Note fine borrow areas and cobble liner features were not included in the wave models, because they would have limited effects on the results.

Table 2. Capoli Slough alternatives

	Alternatives								
Features	A	B2	C4	C6	D3	E3	E4	E5	E6
Island A	x	x	x	x	x	x	x	x	x
Rock Sill A	x	x	x	x	x	x	x	x	x
Island B	x	x	x	x	x	x	x	x	x
Island D	x	x	x	x	x	x	x	x	x
Island E	x	x	x	x	x	x	x	x	x
Island L	x	x	x	x	x	x	x	x	x
Rock Mound I	x	x	x	x	x	x	x	x	x
Island C		x	x	x	x	x	x	x	x
Island E1		x	x	x	x	x	x	x	x
Rock Sill E			x			x	x	x	x
Island K			x	x		x	x	x	x
Island K1								x	x
Island G					x	x	x	x	x
Island J									x
Island H							x	x	x
Island F				x			x	x	x

Alternative A – Stabilization of existing islands. This was considered to be the base project to protect the existing resources from further degradation.

Alternative B – Alternative A features plus restoration/protection of interior islands along Capoli Slough.

Alternative C – Alternative A features, with and without features in Alternative B, plus construction of Island K, K1. The primary purpose of Islands K and K1 are to provide protection of the interior of Capoli Slough complex from excess current and wind-generated wave action from the north. Island F was also added to provide additional protection from wind-generated wave action from the south and east.

Alternative D - Alternative A features, with and without features in Alternative B, plus construction of Island G. The primary purpose of Island G is to provide protection of the interior of Capoli Slough complex from wind-generated wave action from the south and east.

Alternative E - Alternative A features, with and without selected features in Alternative B, and construction of Islands G, K, K1, and/or F. Island F was also evaluated to provide additional protection from wind-generated wave action from the south and east.

METHODS

The ensuing discussion of methods are summarized and/or taken verbatim from Rohweder et al. 2008.

Wind Fetch - Wind fetch is defined as the unobstructed distance that wind can travel over water in a constant direction. Fetch is an important characteristic of open water because longer fetch can result in larger wind-generated waves. The larger waves, in turn, can increase shoreline erosion and sediment resuspension. Wind fetches in this model were calculated using the recommended procedure of the Shore Protection Manual (SPM) (USACE 1984). The SPM Method is used, which uses a larger arc (24 degrees) and probably represents a more real-world condition for the areas evaluated. Wind direction data used within the wind fetch model were collected from the National Oceanic and Atmospheric Administration, National Climatic Data Center (NCDC) (http://www7.ncdc.noaa.gov/IPS/LCDPubs?action=getstate&LCD=hardcode) at the La Crosse Municipal Airport. The specific wind parameter used was the maximum 2-minute average wind direction. Wind data used in this analysis were collected only during the early to middle of growing seasons (April – July) from 2002 to 2006. The data used by 10 degree increments is summarized in table 3. Wind fetch was calculated at 10 degree increments around the entire compass for each management alternative using the wind fetch model. Individual fetch raster outputs were then multiplied by the percentage of wind observed from its respective direction. Then these weighted individual wind fetch outputs were summed to create a final weighted wind fetch model for each particular management alternative, including the no action and future without conditions.

Table 3. Wind speed used in the model runs - 2-minute maximum daily from April – July, 2002-2006 from La Crosse Municipal Airport.

	2-minute daily maximum - miles per hour			
Angle	Average	Minimum	Maximum	Count
10	18.3	12	28	9
20	15.6	10	21	10
30	15.1	12	20	10
40	14.0	9	26	9
50	20.0	12	28	4
60	17.1	12	26	7
70	13.3	10	18	4
80	17.6	9	29	10
90	18.8	12	36	23
100	18.9	14	23	8
110	17.7	12	22	9
120	16.4	9	24	8
130	16.9	9	25	17
140	21.6	15	38	5
150	17.6	13	29	18
160	19.6	10	30	16
170	19.4	13	25	10
180	19.8	10	31	30
190	19.4	12	25	32
200	18.3	8	31	40
210	19.5	12	40	31
220	16.7	9	30	18
230	21.8	14	37	13
240	21.2	9	44	10
250	18.0	10	29	3
260	20.8	13	30	12
270	17.1	9	33	10
280	25.7	12	53	17
290	20.4	9	32	21
300	17.3	10	28	15
310	18.3	10	37	23
320	20.0	13	36	35
330	21.3	9	35	48
340	19.2	12	31	37
350	15.8	9	28	20
360	19.6	10	38	17
Average	19.0	8	53	609

Sediment Suspension Probability Analysis - Many factors affect aquatic plant growth. These may include site-characteristic changes in climate, water temperature, water transparency, pH, and oxygen effects on CO2 assimilation rate at light saturation, wintering strategies, grazing and mechanical control (removal of shoot biomass), and of latitude (Best and Boyd 1999). According to Kreiling et al. 2007, “light, rather than nutrients, was the main abiotic factor associated with the peak Vallisneria shoot biomass in Pool 8.” Wave action has a direct effect on water transparency. When sediments are suspended by wave action, it causes an increase in water turbidity. High turbidity can reduce aquatic plant growth by decreasing water transparency, thus limiting light penetration.

The sediment suspension probability analysis developed for Capoli Slough HREP involved executing the wave models to calculate maximum orbital wave velocity (MOWV) outputs for each potential management scenario and applying these MOWV values to predict sediment suspension probabilities. According to Coops et al. 1991, “maximal wave heights and orbital velocities were concluded to be key factors in the decreased growth rates of plants at exposed sites.”

The MOWV was calculated once daily for the maximum 2-minute duration wind speed over the growing season (April through July) encompassing the 5-year period between 2002 and 2006 (n = 610 days). The MOWV of 0.10 meters per second was then selected to represent velocities required to suspend fine unconsolidated sediments (Håkanson and Jansson 1983).

This analysis provides a worst case indicator of potential for sediment suspension. First, the data used was for a maximum daily 2-minute duration wind speed and direction and therefore is only an indicator of the daily effects. In addition, the underlying assumption of this model is that there is no aquatic vegetation which would dampen wave action. While this may be valid in April and May prior to the emergence of aquatic vegetation, during most of the growing season aquatic vegetation would dampen wave action. The affects on wave actions of new islands and aquatic vegetation (existing and expansions in response to the islands) are likely to have a synergistic effect on sediment suspension. In addition, the affects of wave dampening by bottom friction aren't accounted for.

Bathymetric data used in the wave model equations were obtained from the Long Term Resource Monitoring Program. Table 4 summaries the existing water depths in the study area. The bathymetric data had to be modified when calculating the MOWV for the “No Action” management scenario, since all island areas that were predicted to be lost in that scenario.

Table 4. Water depths

	Acres		
Depth (feet)	Cap Minor	Cap Major	Cap Slough
0-1	0.9	85.0	0.8
1-2	5.3	196.4	4.3
2-3	62.0	255.5	5.1
3-4	548.5	166.5	5.4
4-5	527.0	31.7	5.8
5-6	50.6	7.8	6.8
6-7	7.0	4.0	6.5
>7	12.6	6.5	6.5

RESULTS

Fetch - Weighted wind fetch was calculated for the study for selected potential management alternatives, No-Action and Existing Conditions. The weighted wind fetch results are depicted for Capoli Slough and surrounding area in figures 5-9. Using this weighted fetch analysis approach, it is possible to quantify the amount of wind fetch for each of the separate island alternatives and compare how the addition of potential island structures may affect wind fetch. The ability to decrease wind fetch within the Capoli Slough area would benefit Capoli Slough and surrounding areas by lessening the forces applied due to wave energy and thereby decreasing turbidity. This approach took into account historical wind data. Site-specific wind data would have been preferred but this was unavailable.

Under the no action alternative, wind fetch will increase in the future as the existing islands disappear (table 5, figure 3). Alternative A, which consists mostly of protecting existing islands and shallow areas, would maintain and slightly decrease existing wind fetch, within the Capoli Slough complex (table 5, figure 4). Alternatives B through E provide incremental reductions in fetch (table 5 and figures 4-8). The E alternatives which include the outer barrier Islands K and G would reduce the weighted wind fetch to less than 4,000 feet in Capoli Slough Major area, from the existing and future without conditions of 7,500 and 9,300 feet, respectively. A similar level of reduction would also occur in Capoli Slough proper. In Capoli Slough Minor there would be a reduction in fetch of greater than 1,500 feet over the existing and future without project conditions for the E alternatives.

Sediment Suspension Probability – An indicator of sediment suspension probability was calculated for the alternatives. This indicator of sediment suspension is based on the maximum daily 2-minute duration wind speed sufficient to generate a wave for a given fetch and water depth that would generate an orbital velocity greater than 0.1 meters/second. Orbital velocities greater than 0.1 meters/second will suspend unconsolidated fine sediments. Sediment suspension results are depicted in Figures 9 – 16 and Tables 6-8 highlight differences in potential for fine unconsolidated sediment suspension between the “Future Without”, “Existing”, and selected management alternatives.

This analysis provides a simplistic approach to forecasting wave effects on the suspension of fine unconsolidated sediment particles. Based upon this approach, it is possible to depict changes in sediment suspension probability for several potential island alternatives. By decreasing the potential for sediments to be suspended, there would be a decrease in turbidity. Decreasing turbidity would increase light penetration and, therefore, create conditions more conducive to aquatic plant growth. This approach took into account historical wind data.

As the remaining islands disappear, there will be an increase in the percentage of days with a MOWV capable of suspending fine sediments. With the addition of features for each alternative progressing from A to E, we see decreases in the percentage of days with MOWV capable of suspending fine unconsolidated particles within all three areas, Cap Major, Cap Minor, and Cap Slough. The mean number of days in Cap Major decreases to around 36% compared to 79% and 69% for the Future Without and Existing conditions, respectively. The Cap Minor shows less of decrease, but still fairly substantial. The number of acres in Cap Major (780 acres) shows a significant decline in sediment suspension probability across the alternatives, i.e. the number of acres that has less than 60% MOWV capable of suspending fine sediments increases from 73 acres for Future Without conditions to around 730 acres with the E alternatives (Table 7). Alternatives E4, E5, and E6 produce similar results. In the Cap Minor area (1,214 acres), the acres increase from 524 for Future Without to 1,123 with Alternative E5 for the less than 60% of daily 2-minute duration wind speeds where orbital velocities exceed 0.1 meters/second. A substantial reduction in sediment suspension is predicted to occur for the Cap Slough, Cap Major and Cap Minor areas. This should translate into improved water clarity. Figures 15 and 16 show the reduction in sediment suspension probability for the base Alternative A and Alternative E5. Alternative A shows a little difference from existing, but will reduce suspension probability over the future without action. Alternatives E4, E5, and E6 shows a least a10% reduction in sediment suspension probability over the future without action in the Cap Minor area.

The wind/wave results, especially as it may affect water clarity and vegetation, along with the hydraulic modeling results and other data was used in the Habitat Evaluation Procedures to perform a cost-benefit analysis (see appendix 4).

Cumulative Effects for Lower Pool 9 – The potential cumulative effects of Capoli Slough and other past (Pool 9 Island and Bank Stabilization Projects) and proposed HREPS; Harpers, Winneshiek and Lower Pool 9 islands were evaluated. Some preliminary islands were designed for these future projects (Figures 17 and 18 and Table 9). Substantial modifications of fetch and reductions in sediments suspension would be realized in the 16,500 acres of lower pool 9. The mean percent of days where orbital velocities exceed 0.1 meters would be reduced to 29% from 45% to 40% for the future conditions and existing conditions, respectively.

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Coops, H., R. Boeters and H. Smit. 1991, Direct and indirect effects of wave attack on helophytes. Aquat. Bot. 41:333-352.

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Kreiling, R. M., Yin, Y., and Gerber, D. T., 2007, Abiotic influences on the biomass of *Vallisneria americana Michx*. in the Upper Mississippi River: River Research and Applications, v. 23, no. 3, p. 343-349.

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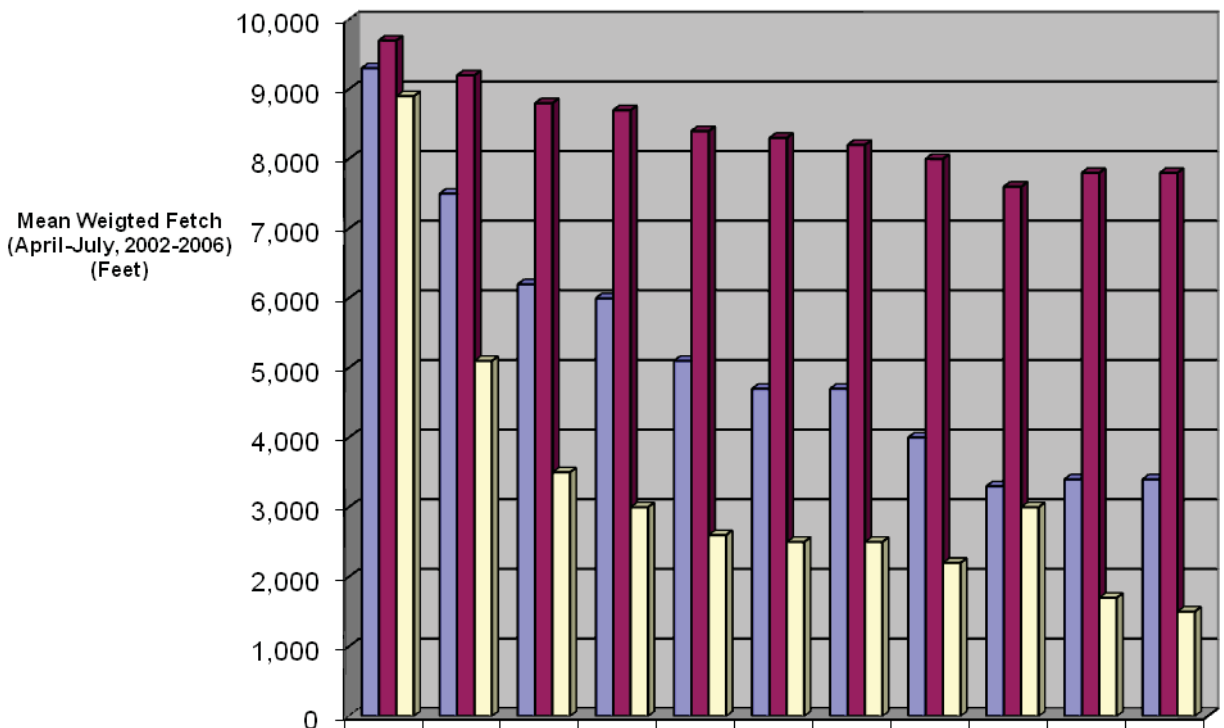
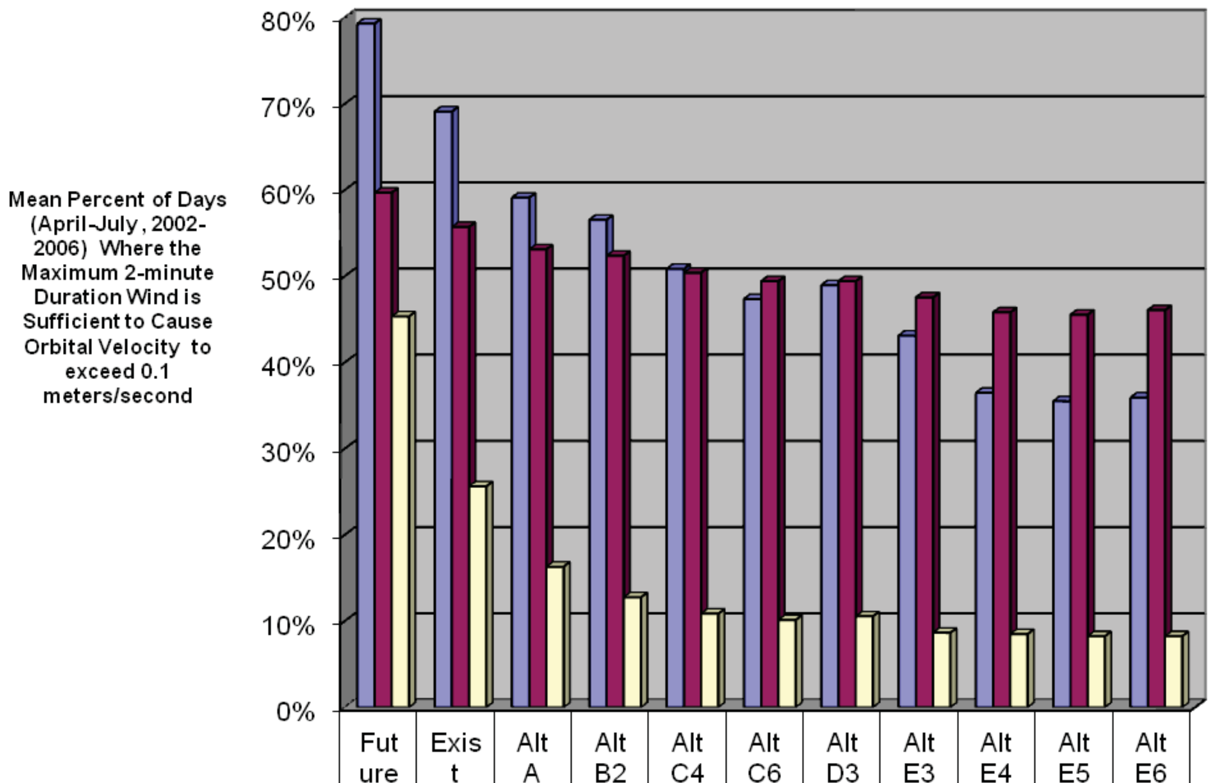
Table 5. Effects of alternatives on mean weighted fetch (April – July, 2002-2006).



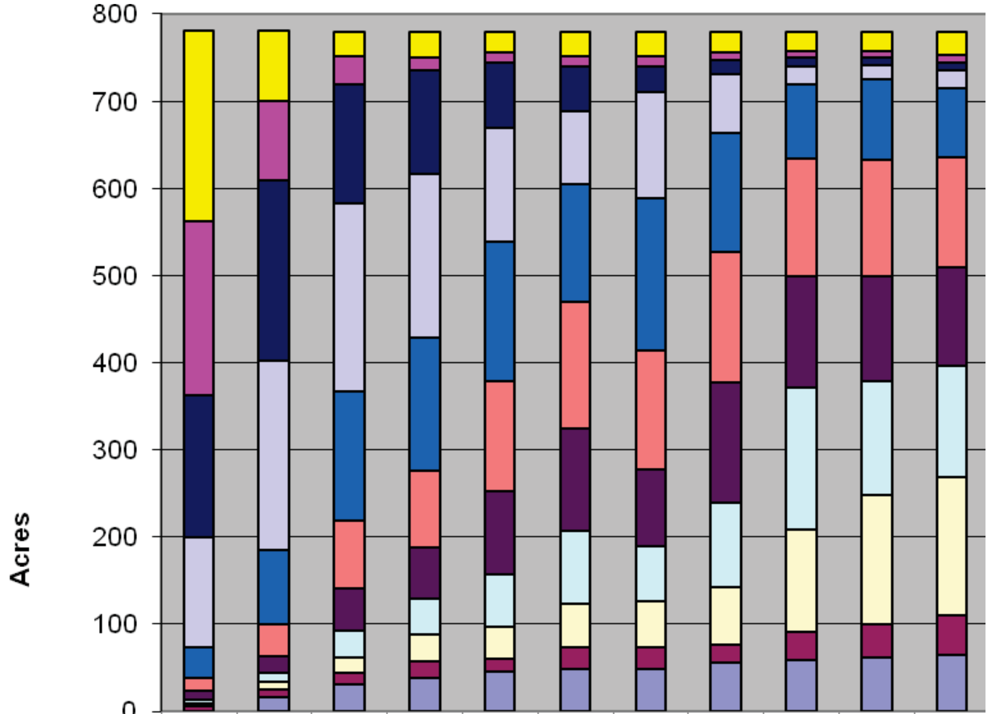
	Fut.	Exist	Alt A	Alt B2	Alt C4	Alt C6	Alt D3	Alt E3	Alt E4	Alt E5	Alt E6
Cap Major	9,300	7,500	6,200	6,000	5,100	4,700	4,700	4,000	3,300	3,400	3,400
Cap Minor	9,700	9,200	8,800	8,700	8,400	8,300	8,200	8,000	7,600	7,800	7,800
Cap Slough	8,900	5,100	3,500	3,000	2,600	2,500	2,500	2,200	3,000	1,700	1,500

Table 6. Mean percent of days with orbital velocities greater than 0.1 meters/second.



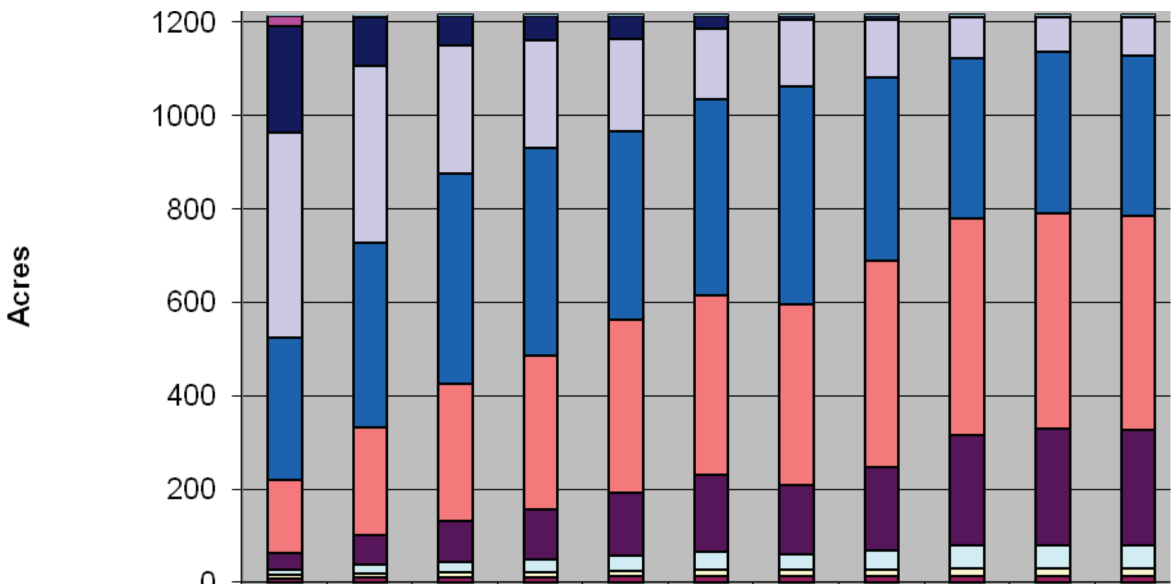
	Fut ure	Exis t	Alt A	Alt B2	Alt C4	Alt C6	Alt D3	Alt E3	Alt E4	Alt E5	Alt E6
Cap Major	79%	69%	59%	57%	51%	47%	49%	43%	36%	36%	36%
Cap Minor	60%	56%	53%	52%	50%	49%	49%	48%	46%	46%	46%
Cap Slough	45%	26%	16%	13%	11%	10%	11%	9%	8%	8%	8%

Table 7. Effects of alternatives on sediment suspension probability (percent of days (April – July) where orbital velocities exceed 0.1 meters/second) in Capoli Slough Major area (780 acres).



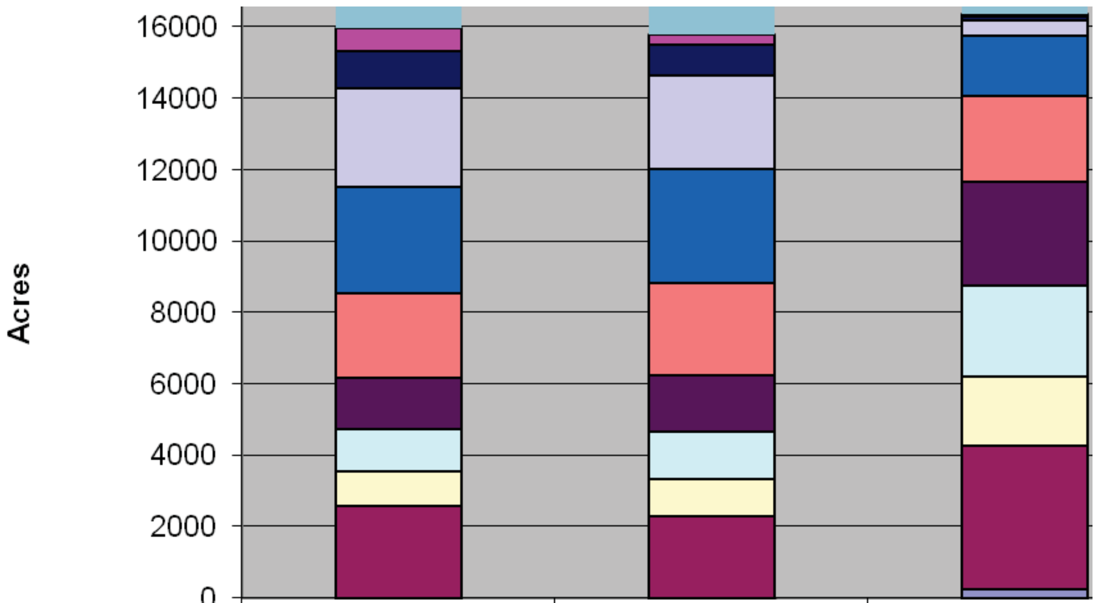
	Fut.	Exist	Alt A	Alt B2	Alt C4	Alt C6	Alt D3	Alt E3	Alt E4	Alt E5	Alt E6
90-100%	218	80	28	30	23	29	29	22	22	22	27
80-90%	199	91	33	16	12	11	11	9	8	8	8
70-80%	163	206	137	118	75	52	30	17	9	9	9
60-70%	127	217	216	188	130	83	121	67	20	15	21
50-60%	35	85	147	152	160	136	176	138	86	93	79
40-50%	15	37	79	89	126	145	136	150	134	134	126
30-40%	10	19	48	58	95	117	88	138	129	121	112
20-30%	5	11	31	41	60	84	63	96	162	130	129
10-20%	4	9	18	31	37	49	52	66	118	150	158
0-10%	5	8	13	19	15	26	24	20	33	38	46
Islands	0	16	31	38	45	48	49	56	59	62	64

Table 8. Effects of alternatives on sediment suspension probability (percent of days (April – July) where orbital velocities exceed 0.1 meters/second) in Capoli Slough Minor area (1214 acres).



	Future	Exist	Alt_A	Alt_B2	Alt_C4	Alt_C6	Alt_D3	Alt_E3	Alt_E4	Alt_E5	Alt_E6
90-100%	1	1	1	1	1	1	1	1	1	1	1
80-90%	22	3	1	1	1	1	1	1	1	1	1
70-80%	229	105	64	53	48	28	7	8	3	2	3
60-70%	437	379	273	230	199	151	143	123	90	76	83
50-60%	306	396	451	445	403	418	468	393	341	346	342
40-50%	155	229	293	328	370	387	387	442	465	461	458
30-40%	36	65	88	109	134	163	149	179	237	249	248
20-30%	11	18	23	26	34	39	33	40	49	50	50
10-20%	8	9	10	11	12	14	13	14	15	15	15
0-10%	8	10	10	11	12	13	13	13	14	13	14
Islands	0	0	0	0	0	0	0	0	0	0	0

Table 9. Effects of alternatives on sediment suspension probability (percent of days (April – July) where orbital velocities exceed 0.1 meters/second) in Lower Pool 9 with Capoli and future HREPs.



	Future	Exist	ALL HREPs
90-100%	612	786	221
80-90%	640	303	60
70-80%	1047	832	102
60-70%	2761	2641	458
50-60%	2978	3210	1663
40-50%	2387	2560	2410
30-40%	1416	1603	2901
20-30%	1192	1303	2552
10-20%	980	1041	1949
0-10%	2555	2266	4019
Islands		23	232

Figure 1. Capoli Slough Layout 2010.

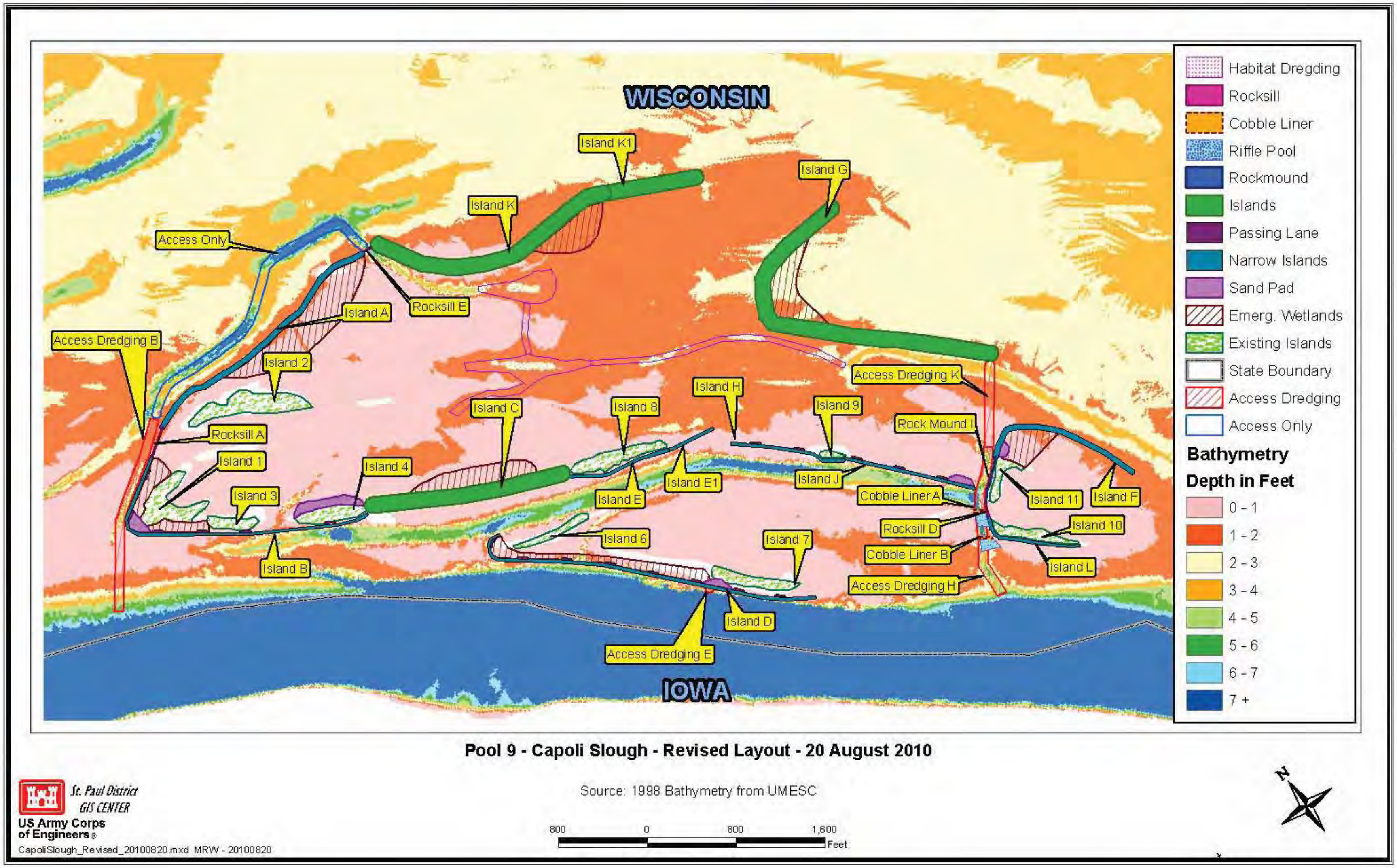


Figure 2. Capoli Slough Study Areas

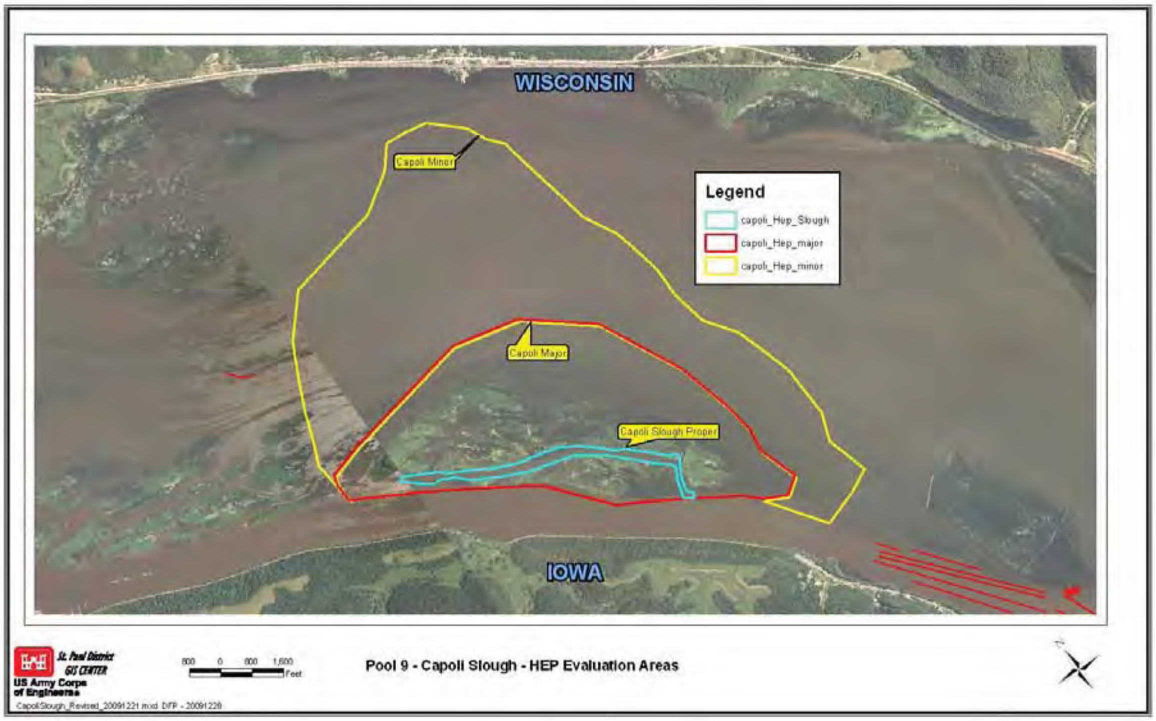


Figure 3. Weighted Fetch for Existing and Future Without Action.

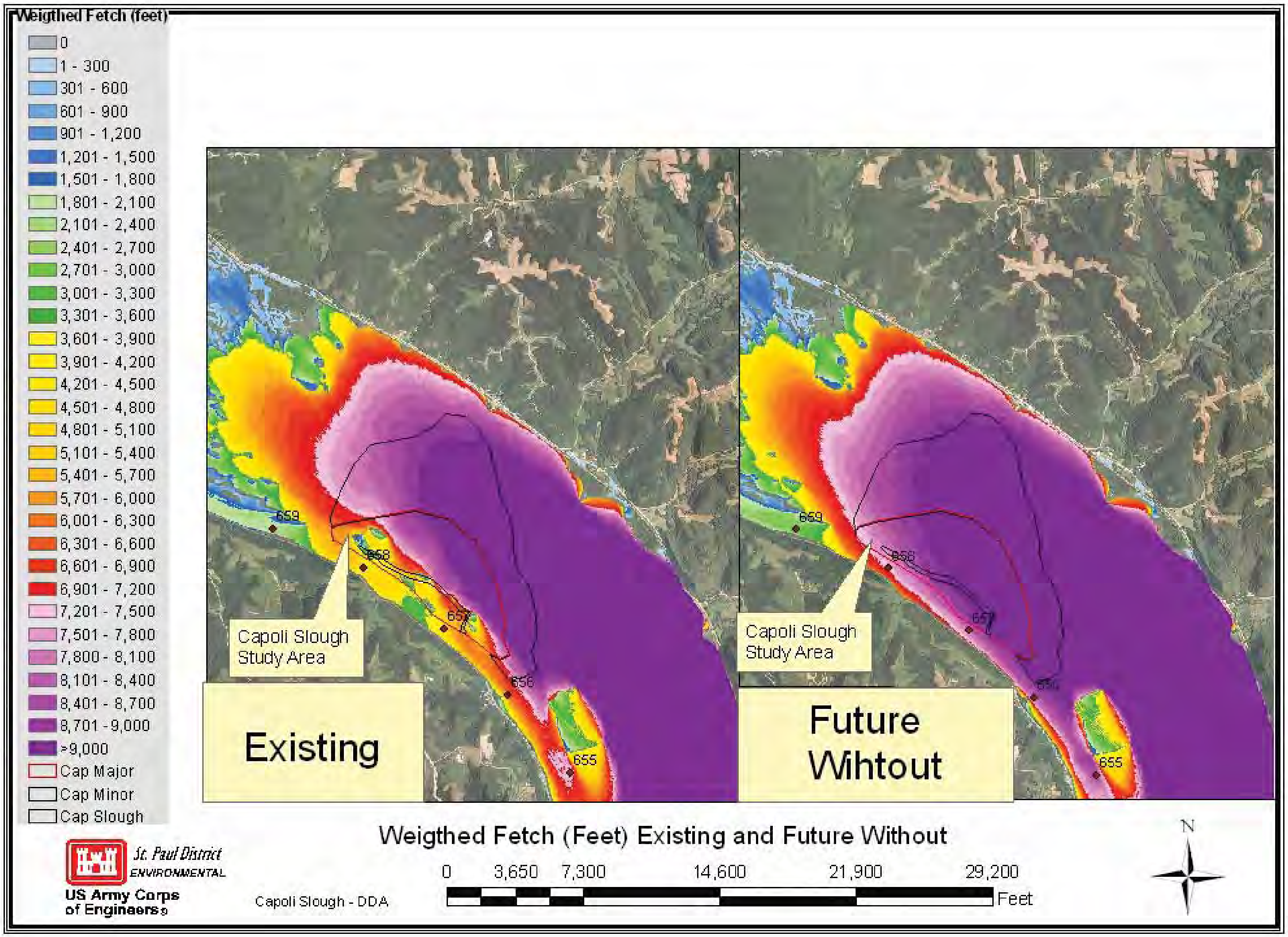


Figure 4. Weighted Fetch for Alternatives A and B2.

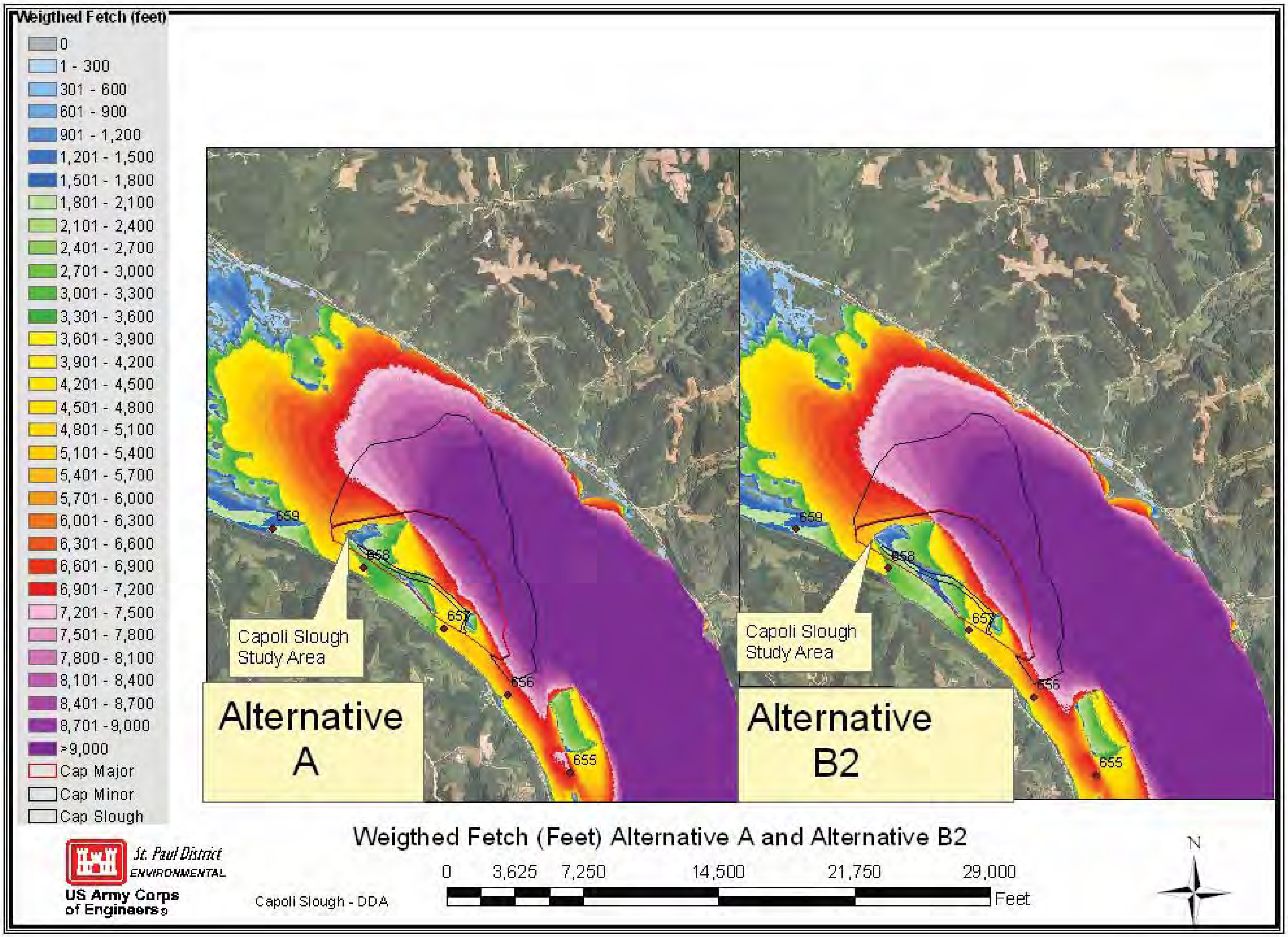


Figure 5. Weighted Fetch for Alternatives C4 and C6.

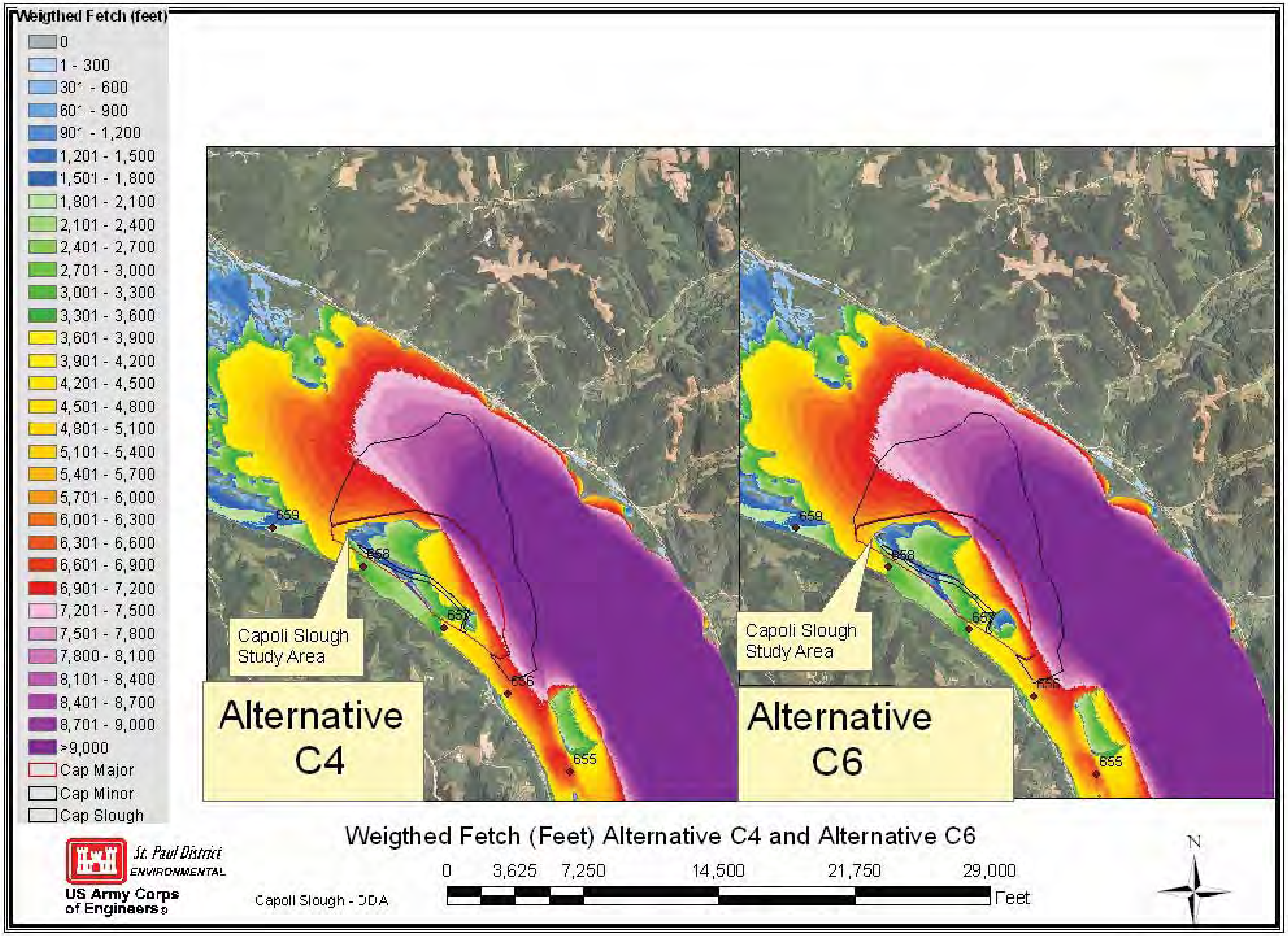


Figure 6. Weighted Fetch for Alternatives D3 and E3.

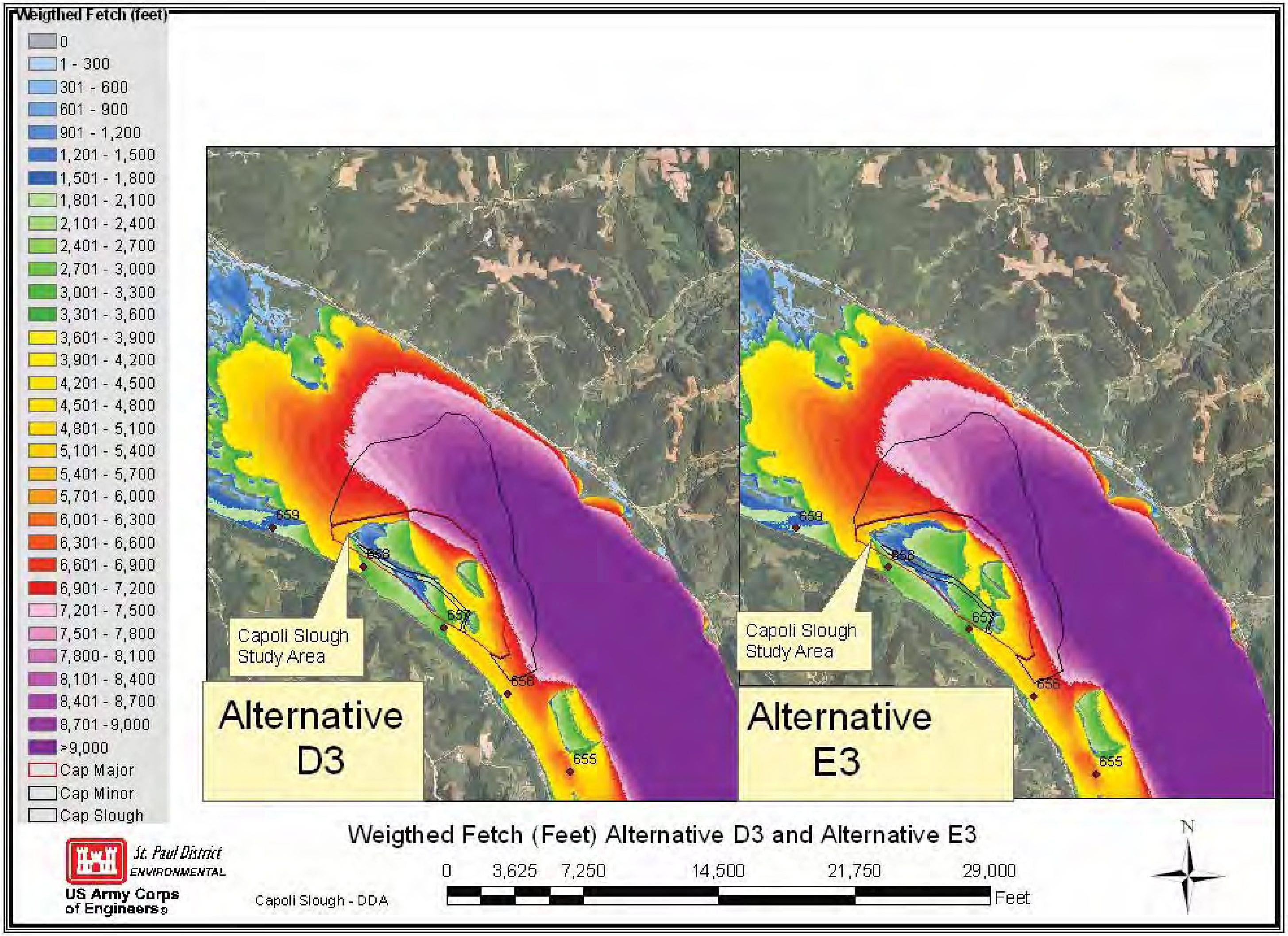


Figure 7. Weighted Fetch for Alternatives E4 and E6.

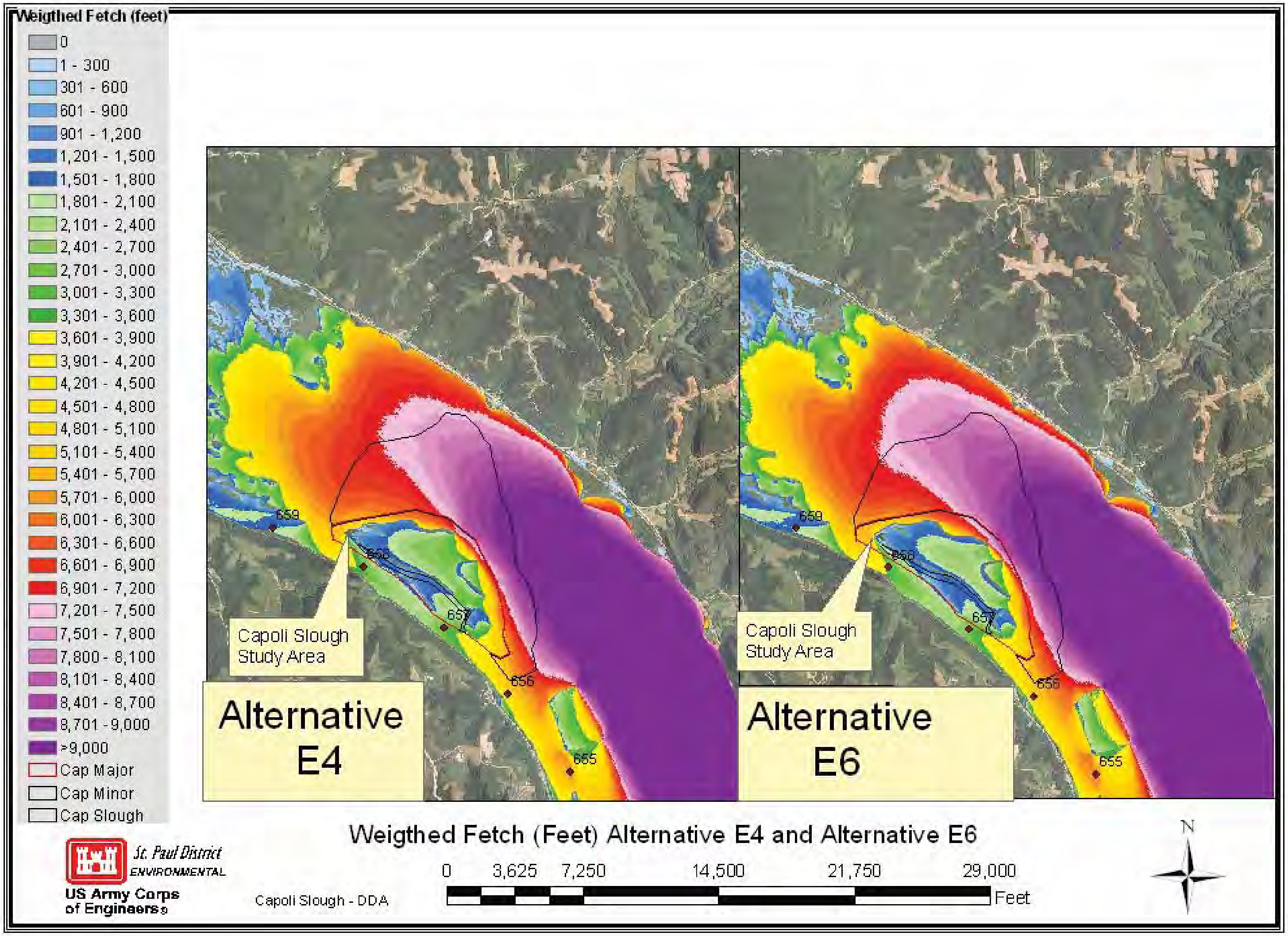


Figure 8. Weighted Fetch for Alternatives E5 and Future Without.

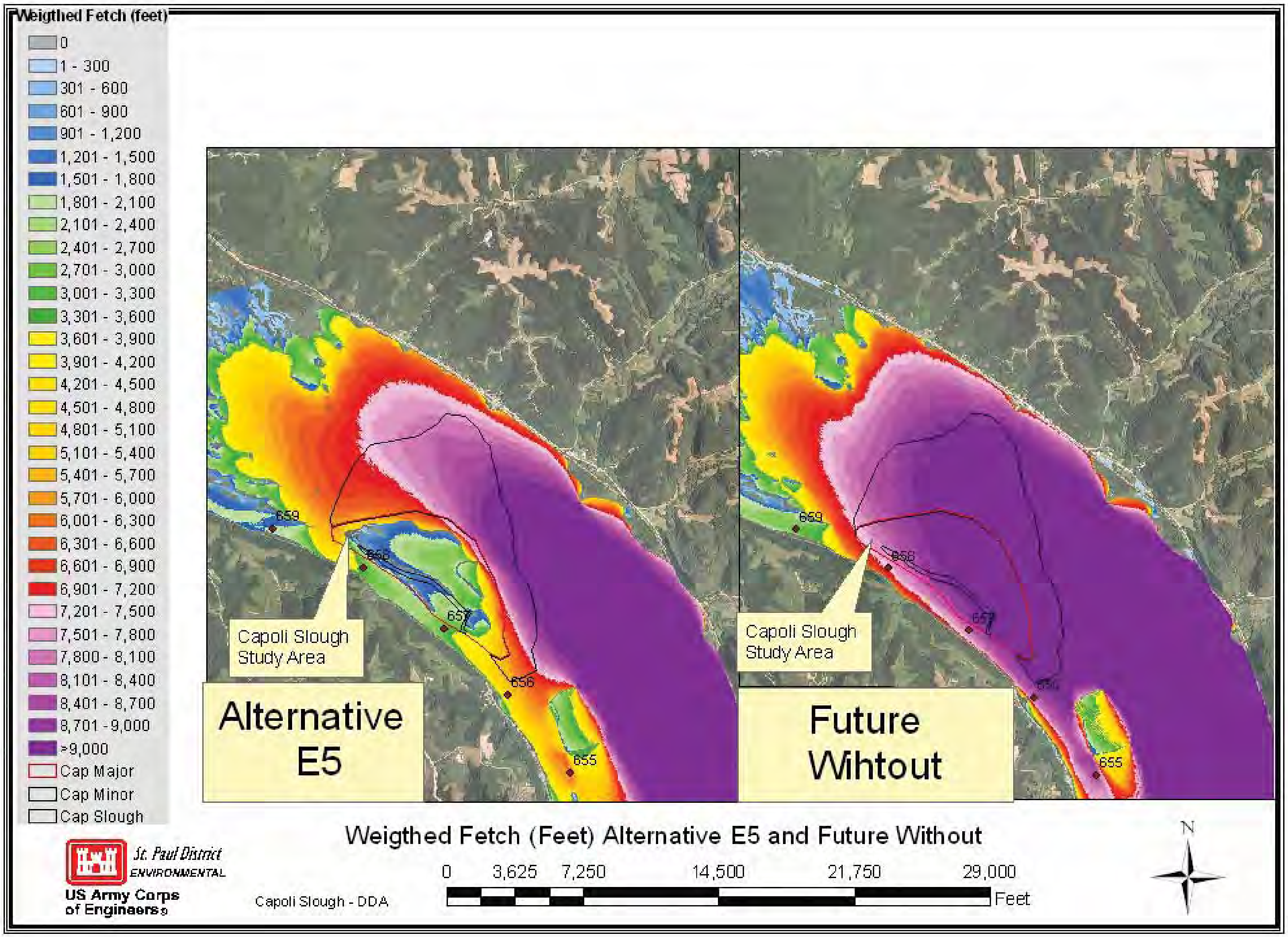


Figure 9. Sediment suspension probability for Existing and Future Without Conditions.

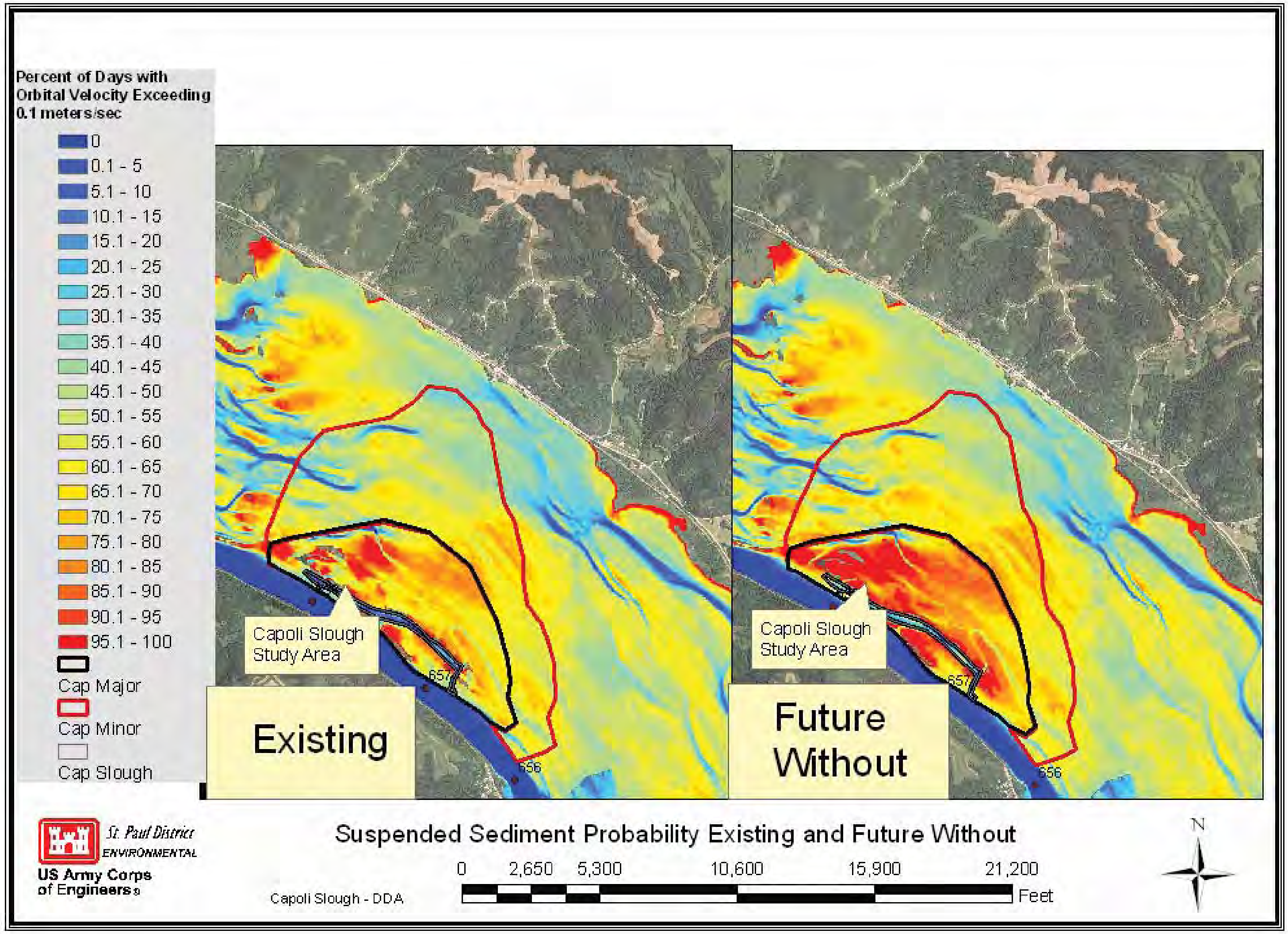


Figure 10. Sediment suspension probability for Alternatives A and B2.

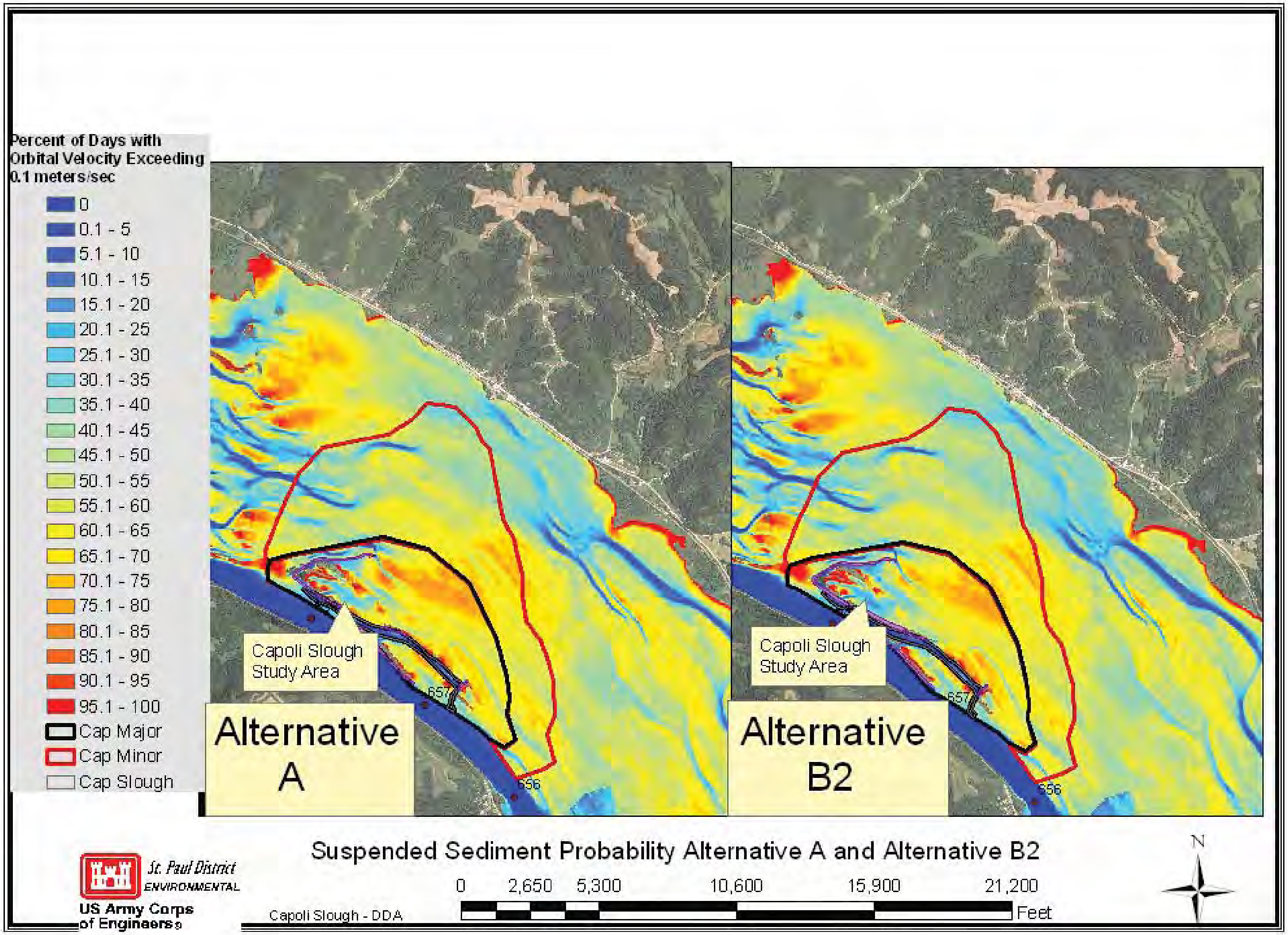


Figure 11. Sediment suspension probability for Alternatives C4 and C6.

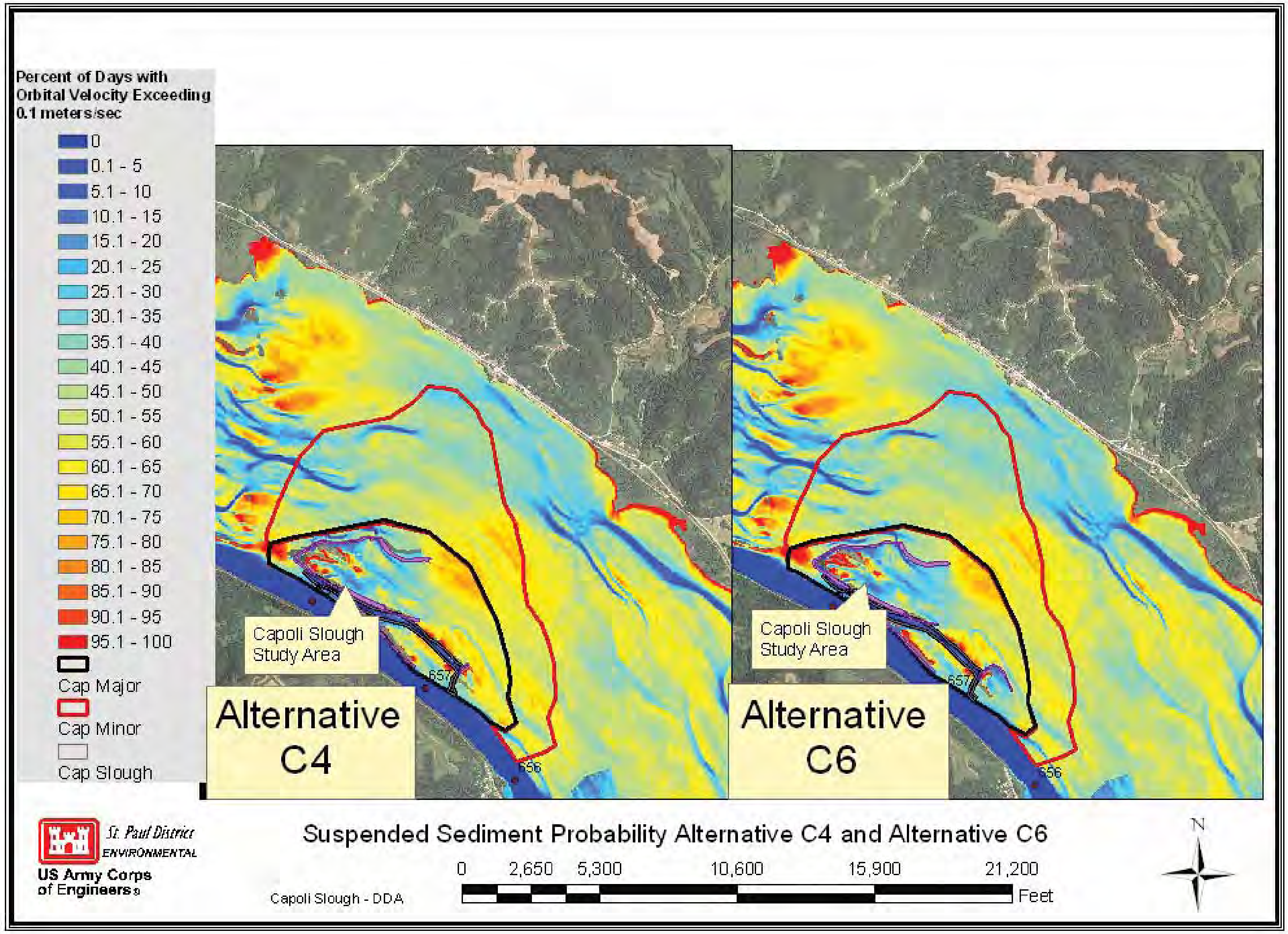


Figure 12. Sediment suspension probability for Alternatives D3 and E3.

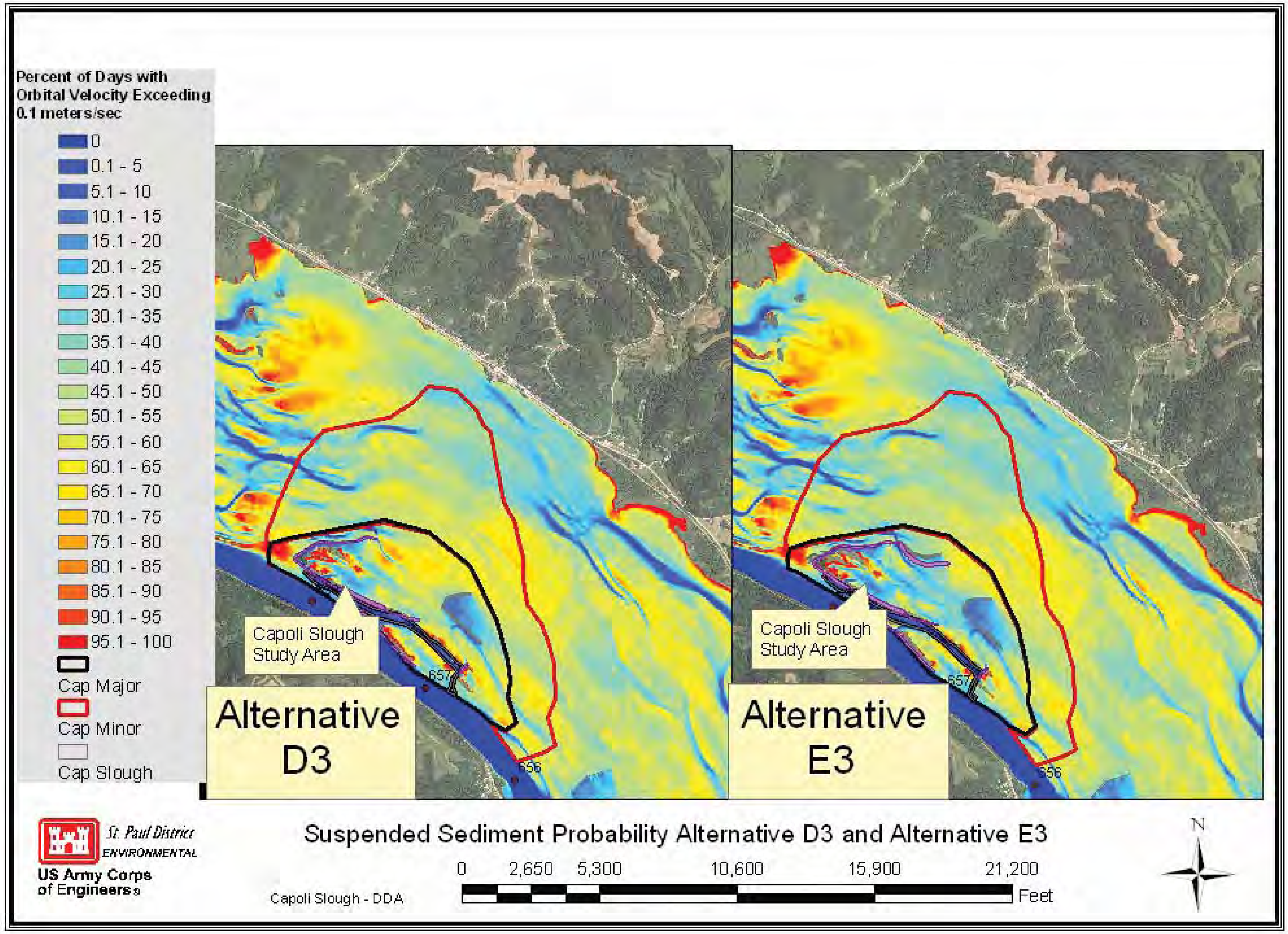


Figure 13. Sediment suspension probability for Alternatives E4 and E6.

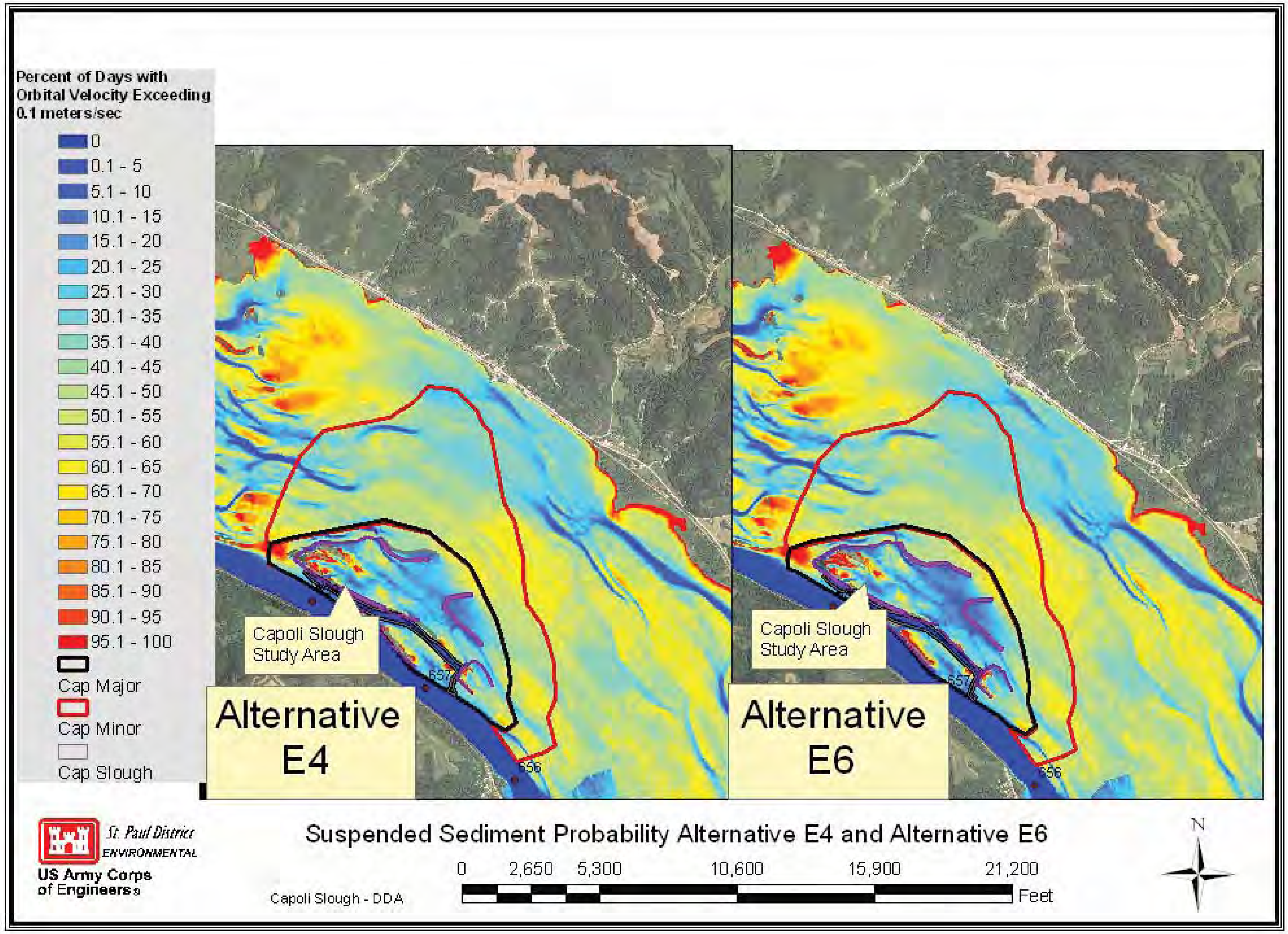


Figure 14. Sediment suspension probability for Alternatives E5 and Future Without.

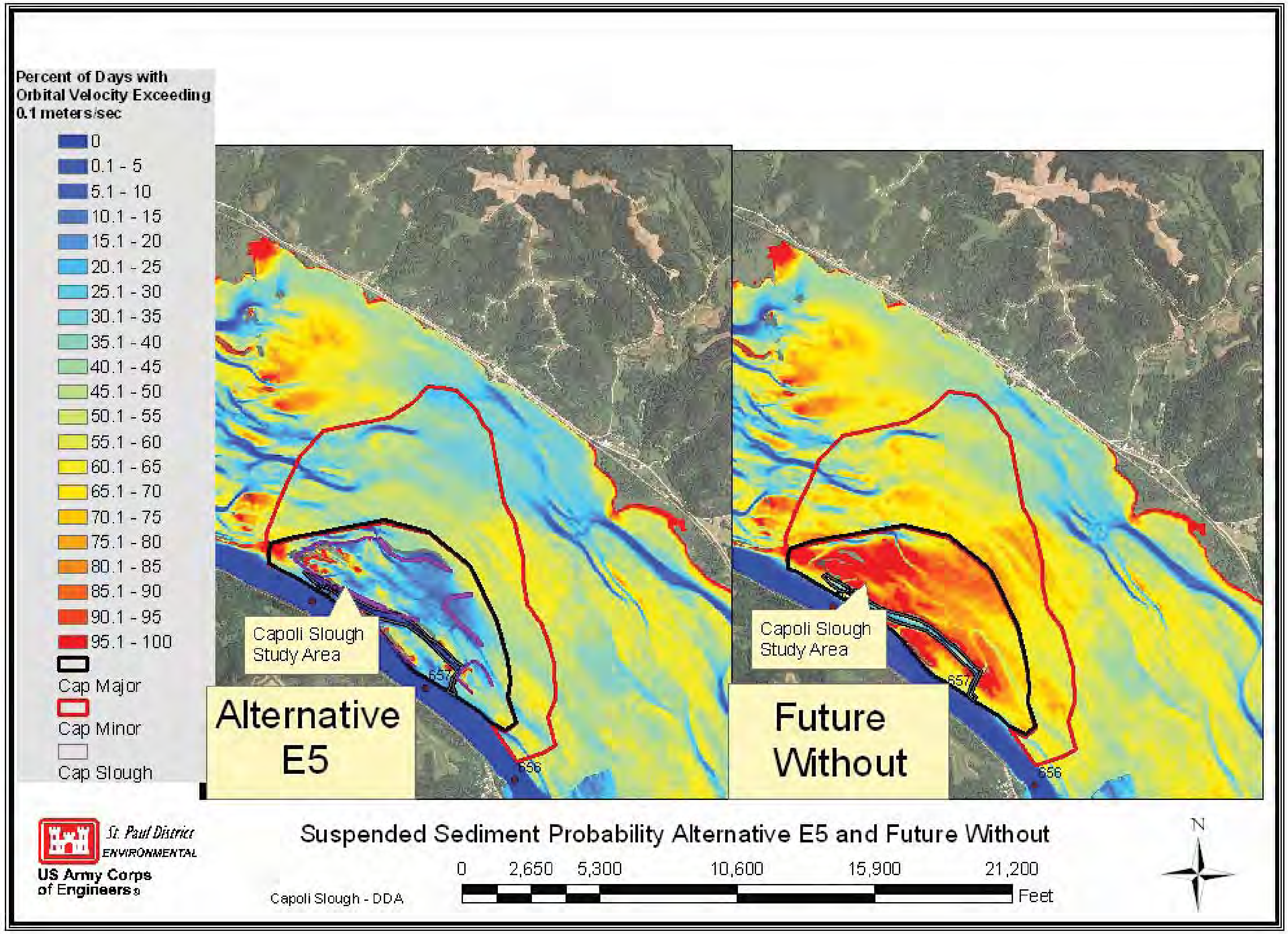


Figure 15. Reduction in sediment suspension probability for Alternatives A versus Existing and Future Without.

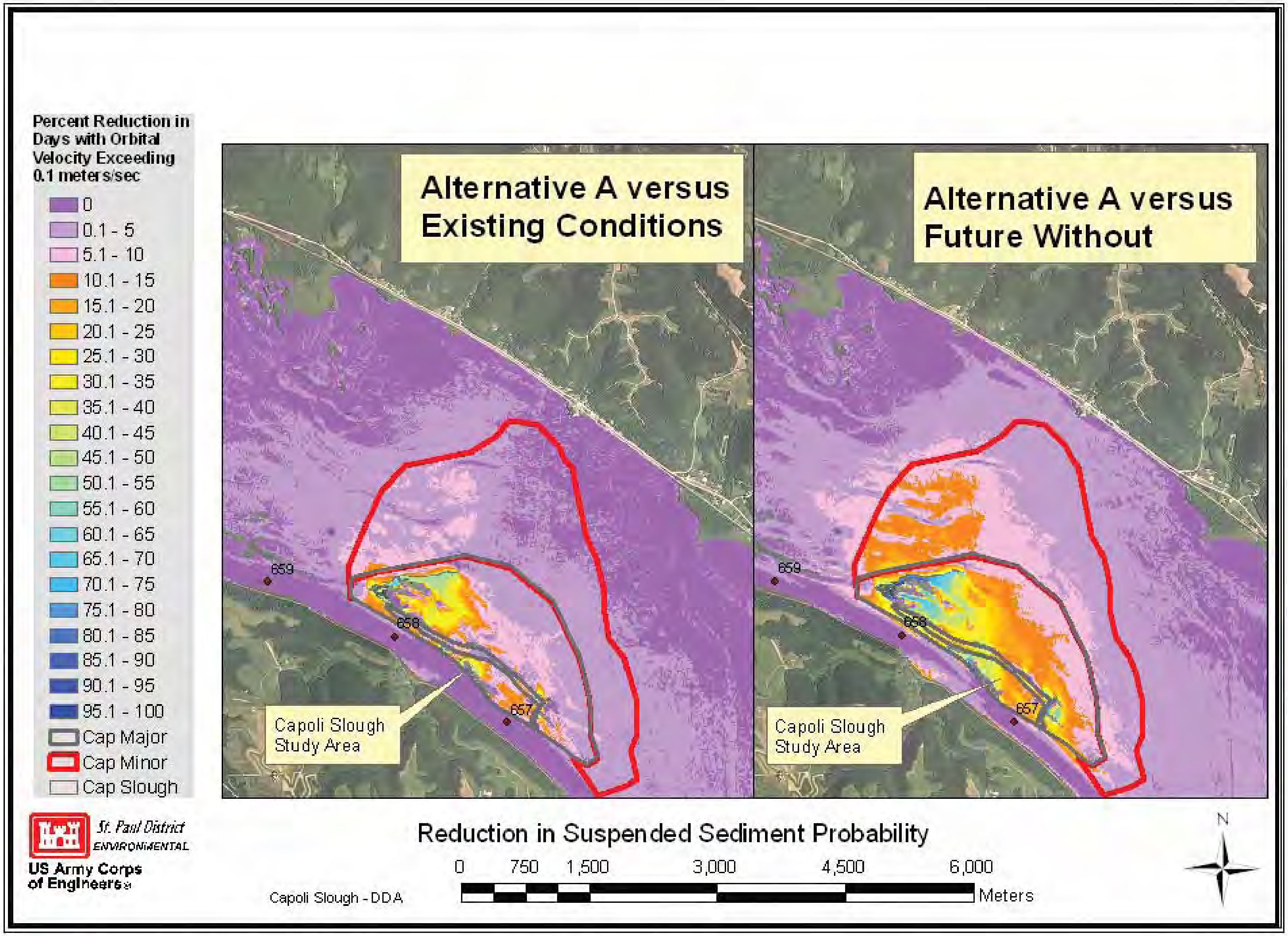


Figure 16. Reduction in sediment suspension probability for Alternatives E5 versus Existing and Future Without.

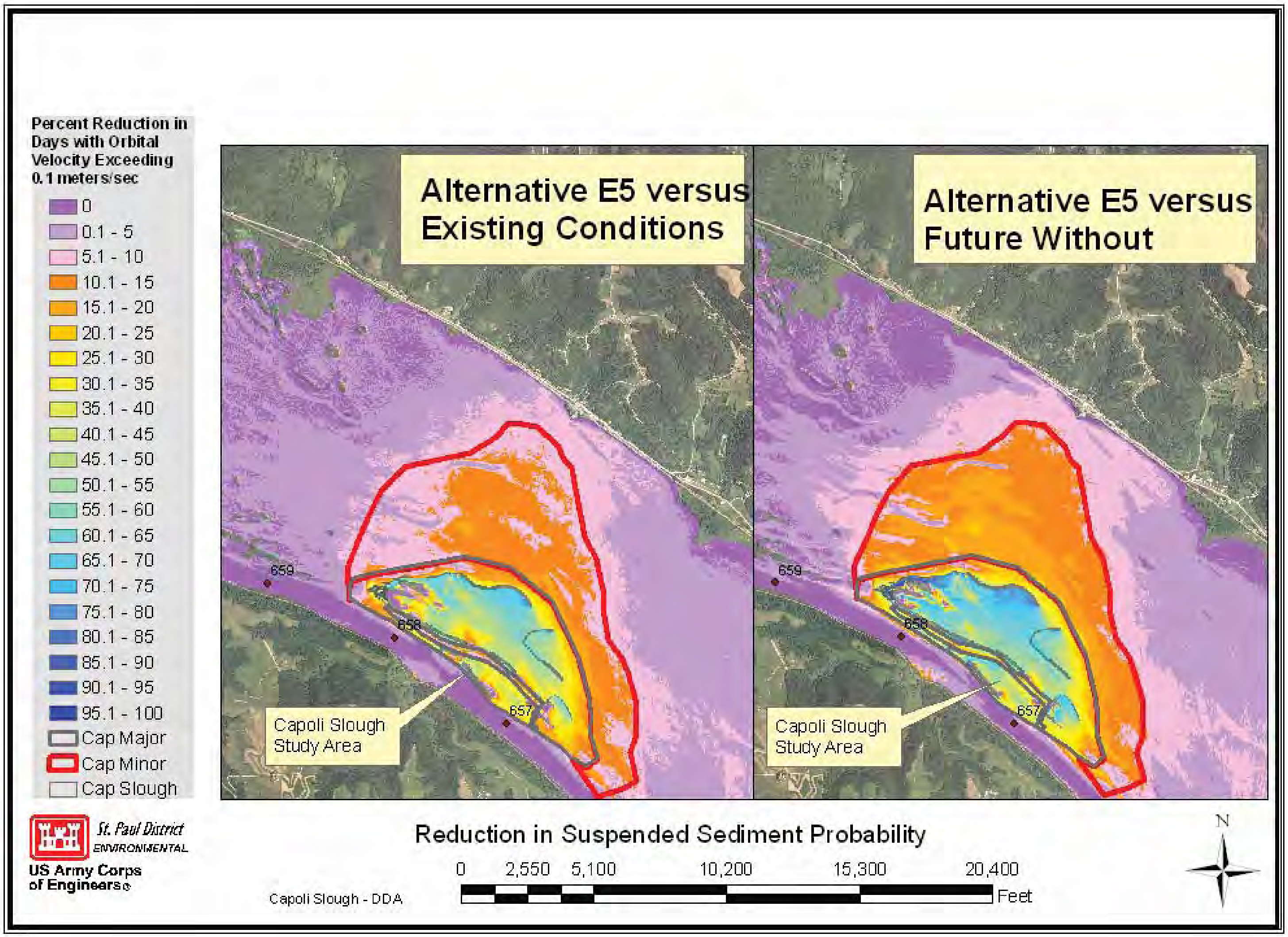


Figure 17. Weighted Fetch (Feet) for Lower Pool 9

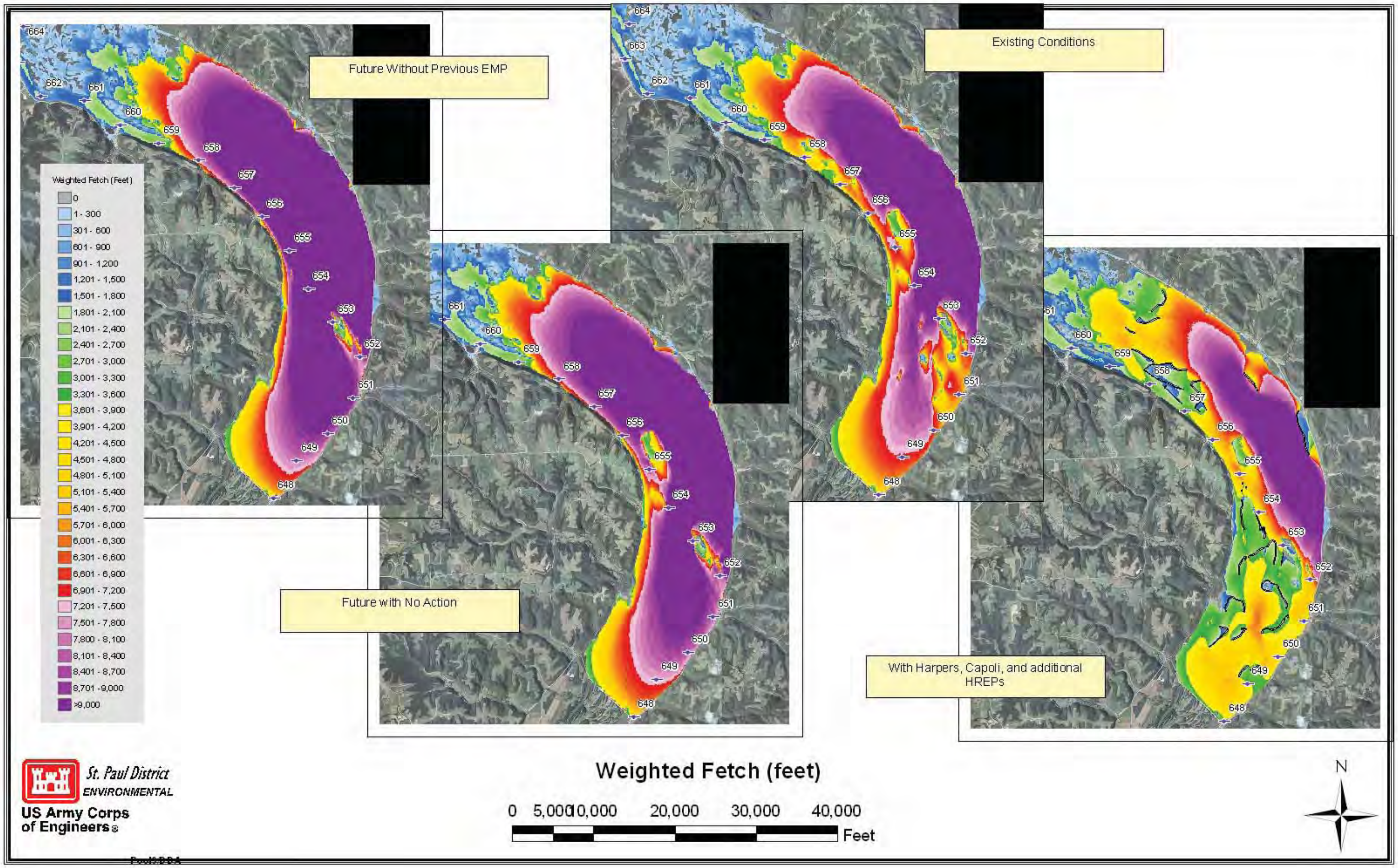


Figure 18. Suspended Sediment Probability for Lower Pool 9.